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CONTROL SYSTEMS DEVELOPMENT DIVISION INTERNAL NOTE 74-EG-20

SPACE SHUTTLE ORBITER VEHICLE STAR TRACKER TEST PROGRAM PLAN

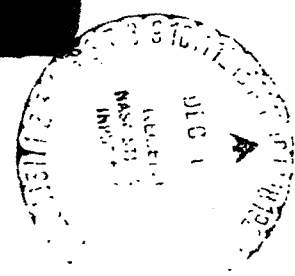
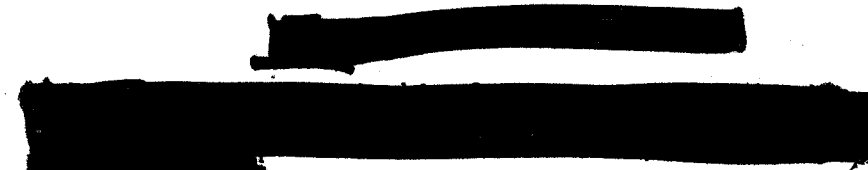
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VEHICLE STAR TRACKER TEST PROGRAM PLAN
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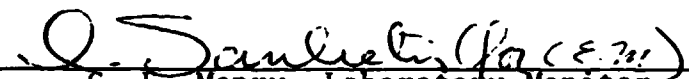
PROJECT SPACE SHUTTLE
SPACE SHUTTLE ORBITER VEHICLE
STAR TRACKER
TEST PROGRAM PLAN

PREPARED BY

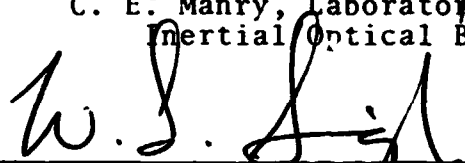


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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
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FOREWORD

The test program plan contained in this document has been written to provide guidance for essential Star Tracker test support to the Space Shuttle Orbiter Program.

It is anticipated that a development model (production prototype) Star Tracker will be obtained from the manufacturer by NASA/JSC for the test program and that the tests will be performed in the Inertial/Optical Branch optical laboratory located in Building 16A, JSC.

ACKNOWLEDGEMENTS

This document was prepared by Lockheed Electronics Company, Inc., Aerospace Systems Division, Houston, Texas, for the Control Systems Development Division at the Lyndon B. Johnson Space Center (JSC) under Contract NAS 9-12200, Job Order 35-459. It was written by Robert A. Smith, Principal Engineer, and approved by James M. Lecher, Acting Supervisor of the Guidance Systems Section, and William R. Labby, Manager of Guidance, Control and Instrumentation Department, Lockheed Electronics Company, Inc.

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1.0 INTRODUCTION

1.1 Background

In the near future the Shuttle Orbiter contractor, Rockwell International, will award a contract for development of a flight model Star Tracker (ST). After the contract award and subsequent vendor performance, it is anticipated that a development model ST will be tested at JSC.

1.2 Objective

The development model test program will be performing tests which will permit an early evaluation of the tracker's performance prior to completion and testing of the final flight models. Major discrepancies and/or design faults detected in the JSC test program can then be corrected if the evaluation is conducted expeditiously and followed by timely reports.

1.3 Program Organization

This test program is divided into the following phases:

- Test equipment preparation
- Prototype baseline/acceptance tests
- Prototype total performance tests
- Prototype special tests

The test equipment preparation phase will include the design, fabrication, checkout and calibration verification of all devices required to complete the test program. Major

emphasis will be placed on hardware components. Software for recording, handling, and reducing data will also be prepared.

The prototype baseline/acceptance test phase will fulfill the need for a "quick look evaluation" of performance characteristics and acceptance criteria verification prior to beginning a more comprehensive evaluation in subsequent phases. This information can be used to establish priorities for following test phases if design problem areas become apparent.

The prototype total performance phase will include a series of thoroughly comprehensive tests to establish a final set of operating capabilities. It is in this phase that questionable performance indicated by the baseline phase can be completely investigated with the priority schedule suggested by previous phase results. Test procedures can be established and verified and all design problems investigated for change determinations. Yet, during the phase, certain procedural modifications may be required to deepen investigation levels or pinpoint problem areas.

The prototype special phase will include a series of special tests to determine ST versatility, software integration, Inertial Measurement Unit (IMU) alignment procedures and techniques, etc., required for the Shuttle program.

2.0 TEST PHASE DESCRIPTION

The following paragraphs contain several outlines of test phases with some discussion of basic techniques for each phase of the program.

2.1 Test Equipment Preparation

The initial program preparation activity will include selection, design, fabrication, and calibration of test equipment and data collection systems required to fulfill subsequent test phases.

2.1.1 Test set concept. The test set design will be created as a unitized, reproducible model which can provide most of the apparatus required for a full test program. The unit will be transportable and capable of setup for testing in normal lighting and ambient temperature conditions. The ST will be mounted onto a test set adapter fixture and the various test set modes used to perform a maximum number of operational and functional tests without removing or adjusting the ST position. Control and power for the ST will be provided by an associated manual control unit and power system. Other panels and devices on this control unit can be used to operate motion tables, adjust source intensities, and control other accessories mounted on the test set which provide proper target outputs and position. Data collection will be accomplished by an external calculator/computer system which receives information from an ST Computer Interface Unit (CIU). Return control of ST operations will be accomplished through the same device.

The test set will have components that can provide correct ST targetry to permit collection of required test data.

2.1.2 Star field simulator. A star field simulator, having 121 star targets spaced throughout the ST total field of view, will be the primary source for the test set. The

star target located in the center of the field will be used as the boresight reference position for the ST simulator alignment. All other targets (to be determined later) will be used for axes roll reference. These other targets in the field will have accurately known angular displacements and uniform brightnesses.

The simulator target plate is located at the focal plane of a high-resolution three-inch diameter collimating lens. Target stars are equally illuminated at the measurable energy levels required for the type of test performed.

2.1.3 Movable star target X-Y translator. A mechanical stepper, motor-driven X-Y translator table will be used to provide a single star target which may be translated at known rates to accurate field locations. This target star, which is affixed to a point on the movable table, will be positioned at the focal plane of the lens specified in section 2.1.2 and dual optical paths to the ST objective will be provided by mirror/beam splitter arrangement. Manipulation of the table will be done by manual or calculator-controlled auxiliary equipment. Target star brightness will be controlled and measured according to the requirements of the particular test being performed.

2.1.4 Background simulator. An adjustable, measurable light source will be provided for ST full field background illumination. The device will be placed in the optical path via a beam splitter arrangement to provide uniform background around any star target being provided by the simulator and translator.

2.1.5 ST mounting fixture. The ST will be mounted on a special test set fixture to provide accurate boresight and roll axis reference for the ST/target simulator position. The fixture will closely duplicate the ST mounting interface to the Shuttle Nav base. Initial alignment of the test set ST/target simulator position and periodic alignment recheck will be provided. This fixture will also provide thermal isolation of the ST from the test set.

2.1.6 Test set and ST control unit. A manually operated control unit with signal check and readout points will be provided. It is envisioned that the necessary controls, power supplies, meters, and other test devices will be mounted in one- or two-instrument racks as required. Since the test set will be operable while under a lightproof cover, it is anticipated that all changes of target position and brightness can be controlled and monitored from the control unit. The CIU will be installed in this unit with proper monitor points as needed. In the event that certain test set operations must be remotely controlled by calculators or computers, the necessary interface connections and controls will be a part of the control unit.

2.1.7 Data collection system. The collection of data from test set operation will be done by one of three methods listed below, depending upon the type of test being performed.

- Manual
- Calculator/Coupler
- Computer

In addition to the collection of data, provision of certain automated control signals to the ST and test set

components may be required. These controls can be programmed and generated by calculator/coupler or by an external computer. Definitive details of these methods will be discussed in subsequent documentation.

2.1.8 Auxiliary test equipment. Some types of test apparatus are required which are not practical elements of the test set. These units will be designed as auxiliary test components. In most cases, usage requirements for these units are limited to specialized tests which require neither repetition nor the employment of highly accurate position adjustments that are found in most other test set operations. Currently, a need for the following three units is envisioned:

- Spectral Response
- Tracking Bandwidth
- Standard Star Source

These units will be designed and fabricated concurrently with the test set. Subsequent documentation will describe their design, construction, and use in the test programs. Other currently available devices are the Farrand Two-Star Simulator, Solar Simulator, and the Horizon Illumination Simulator. These devices will be employed for special tests.

2.2 Prototype Baseline/Acceptance

The prototype baseline/acceptance test phase will provide a means of early verification of the ST performance after receipt of the unit at JSC. The test phase will emphasize operational and performance aspects of the contractor acceptance tests. It may be desirable to verify other baseline

elements prior to beginning subsequent evaluation testing. Since the tests that will be performed are similar or identical to those performed at the contractor's facility, two advantages can be realized. First, ST performance results can be compared to contractor test data to determine if the equipment survived shipment satisfactorily. Secondly, the utilization results of JSC test equipment can be compared with the equipment used in different test sets to determine the existence of data discrepancies.

2.2.1 Test descriptions. The types of test activities to be done in this phase will be similar to those performed at the contractor's facility during the final acceptance of the product prototype. Support test sets constructed and verified during phase one of this plan (section 2.1) will be used. The types of tests to be performed are described in general and the final test program determined at a later date as the contractual effort progresses and sequence definitions are formulated.

2.2.2 Test equipment checkout. Test sets and supporting equipment will be calibrated, adjusted as required, and promptly prepared for testing.

2.2.3 Functional test sequence. All functional testing will adhere to the following sequence.

- a. Electrical interface signals. – electrical interface signals will be verified. The amplitudes and timing relationships for discretes and enables will be measured. Electrical connectors used for input/output (I/O) will be checked for proper connection as required by the specification.

- b. Digital I/O format and timing. — the ST test unit will be used to determine the quality of the digital I/O of the ST. All conditions of digital command unit words will be exercised to determine proper formatting and operation. Waveform measurements will be made and compared to digital I/O specifications.
- c. Mechanical interface. — repetitive mounting and alignment characteristics of the ST will be partially checked during the Mechanical Interface Phase. The extent of the tests will be determined by the design and data analysis.
- d. Electrical power characteristics. — input power characteristics of the tracker will be checked to determine power input, voltage fluctuation effect, ripple component effect, and primary input terminal spiking, or interference caused by the presence of ST.

2.2.4 Performance test sequence. The test sequence consists of the following steps.

- a. Accuracy test. — star position maps will be taken and evaluated to determine the ST target location accuracy needed in all sections of the field of view.
- b. Field dimension test. — the extent of the ST field of view will be measured. Targets will be acquired and tracked to determine the synonymity of acquisition and tracking capability within the total optical field of view.

- c. Sensor photo cathode uniformity. – the sensitivity of the sensor photo cathode to typical star radiation will be measured in selected points of the ST field of view to determine the sensitive surface degree of uniformity.
- d. Magnitude/angle target discrimination. – this test will determine the ability of the ST to acquire and track star targets of varying magnitudes and angular separation.
- e. Background tolerance. – this will test the capability of the ST to acquire and track star targets with simulated background levels.
- f. Angular tracking rate. – this will determine the capability of the ST to acquire and track, within accuracy specifications, a star target while moving at specified angular rates. In addition, the target "pull away" rate will be ascertained.
- g. Star target threshold. – this test will determine the dimmest star target which the ST can acquire and track. Attempts will be made in several selected points in the field of view to check consistency.
- h. Sun/earth brightness protection. – the ability of the sun/earth brightness sensor/shutter system will be tested to determine its sensitivity and time of action.
- i. Horizon and sun illumination tolerance. – the deleterious effects to ST ability to acquire and track a designated star target while the objective lens/sun shade combination is exposed to simulated earth horizon and sunshine illumination will be tested.

Levels of illumination and offset angles of bright sources will be measured to determine operational limits.

- j. Target brightness dynamic range. — a test to determine the effective star target brightness range of the ST will be made. Data will be checked to evaluate dynamic range, activation of attenuators, "change gain" circuitry operation, and error voltage observations for detection of position shift. Acquisition and track operations will be verified at the required operational range limits.
- k. Offset acquisition. — the operation of the offset acquisition technique will be tested to determine speed of operation, accuracy, scale factor, and rejection characteristics of star targets located near the desired image. Target brightnesses will be varied to determine the threshold of reliable operation.
- l. Acquisition time. — the time required to automatically acquire a star target located at various point in the field of view will be determined by this test. Target brightness will be varied to ascertain any effect on acquisition time, particularly near the low threshold level.

2.3 Prototype Total Performance

After completion of the first phase of the test program and subsequent preevaluation, the prototype total performance phase can begin. Emphasis will be given to ST operational areas which have shown, as a result of phase one tests, the

need for further investigation. Even though a series of predetermined tests will be planned for use in this phase, considerable leeway can be granted in rearranging or modifying the test plan because of phase one disclosures or changes in design concepts which may exist at some later time in the overall ST program.

2.3.1 Test descriptions. The particular test types discussed in this document are only a guide as to what may be included in the final test plan. Previously used support test equipment will serve in this phase where possible. It is conceivable that additional test elements will be required and constructed.

2.3.2 Test equipment checkout. Test sets and support equipment will be calibrated, adjusted, and prepared for continuation of the test program. Any subsequent test devices will also be calibrated and verified before utilization in the program.

2.3.3 Functional test sequence. A requirement for retest of electrical interface, digital I/O format and timing, mechanical interface, and electrical power characteristics does not exist for this phase unless changes have been made in the prototype or the test equipment.

2.3.4 Performance test sequence. This sequence will consist of the following steps.

- a. Spectral response. — the overall ST system spectral response will be measured and recorded.

- b. "Firefly" interference.— the susceptibility of the ST operation to "firefly" type false targets will be determined. Capture effect from a desired target, relative brightness of a desired and undesired target, and the rate between the targets will be measured and evaluated. Methods of rejecting false targets will be developed and tested.
- c. Modulated brightness varying targets.— the reaction of the ST to targets with modulation or varying brightness will be tested. ST ability to sustain track and error output quality will be investigated.
- d. Target size/shape effect.— determinations of any deleterious effects will be made. This will include incorrect position data produced by targets of various sizes and shapes.
- e. Tracking bandwidth.— measurements of the ST tracking bandwidth and error output bandwidth will be made.
- f. Multiple star target test.— this test will determine the effects of multiple star targets within the field of view. Numbers of stars, their relative nearness to desired targets, and brightness variations will be some of the changes created to perform the tests.
- g. Mounting pad repeatability.— accuracy tests involving the removal and replacement of the ST to the test set mounting fixture will be conducted to determine the repeatability, or durability, of the mounting system.
- h. Output channel noise measurements.— measurements of the noise found on the output error and target magnitude channels will be made. Amplitude and frequency domain data will be taken.

- i. Stability tests. – this will include comprehensive tests that will determine the stability of the ST in various methods of use. Temperature, boresight, and mechanical stabilities will be determined by various techniques, depending upon the area of interest.
- j. Special tests. – as the program progresses, additional tests to further explore problems, noted deficiencies, and specification deviations will be conducted as considered necessary during this program phase.

2.4 Prototype Special

As previously mentioned, this phase will include all possible special testing which can be performed while the ST is available. During the activities of the first and second phases, it is expected that problem areas will appear and operational questions arise which will clearly indicate the types of tests necessary in this phase. Analysis of previous tests and refinement of some test techniques during the prototype special phase will be used to create a special purpose test program.

3.0 TEST CONFIGURATIONS

3.1 Laboratory Tests

The test set and all auxiliary equipment will be used to conduct the laboratory sequences outlined in a definitive test plan. The total test configuration will be arranged so that manual or automated tests can be conducted according to data

requirements. The ability to perform a limited number of tests under thermal vacuum environment and the placement of the ST on the Guidance and Navigation (G/N) tracking platform will be available. Tests performed in later phases may require reconfiguration of the test set and procurement of additional auxiliary or test set mounted components.

3.1.1 Test set manual control unit. The manual control unit will provide primary control of the ST and test set components. It will house the power supplies and control the switching, the source output adjustments, the output displays, the ST/computer/calculator interface logic, and the star target position controls.

3.1.2 Laboratory computer. The 24K memory, 16-bit computer available in the G/N laboratory will normally be used for guidance and navigation equations, data acquisition, and Dynamic Motion Simulator (DMS) control. The computer can also be used with the CIU for the purposes of data acquisition and ST control.

3.1.3 Computer peripheral devices. The following computer peripheral devices can be used to support the test program:

- Keyboard/printer for manual communications
- Magnetic tape unit for data collection and program storage
- Rotating memory storage for program and data storage
- Keyboard and CRT display unit for quick looks at selected data

- Line printer
- Card reader
- Datapoint recorders

Additional data processing can be performed from the magnetic tape outputs by using the Building 12 computer facilities.

3.1.4 Laboratory calculator. A Hewlett-Packard 9830 Calculator/Coupler combination can be used for the majority of the ST tests because it has control and data acquisition capabilities similar to the laboratory computer. The computer will be needed for more complex testing involving navigational equation manipulations. With the addition of a high speed Punched Tape output and associated Punched Tape reader, the calculator/coupler can adequately receive data from the CIU for subsequent analysis.

3.2 Guidance and Navigation Tracking Laboratory Tests

It is required that testing be conducted with the ST mounted on the G/N tracking laboratory platform while using real star targets. Data and control channels will be needed when using the laboratory computer, while the calculator/coupler can be used for local control of the tracking platform. Communication between the ST/CIU can be accomplished through high-quality dedicated cable lines. Depending upon the cable length and type used, it is possible that some form of auxiliary buffer equipment may be required.

The ST manual control unit will also be implemented within the system to provide local monitoring and control as needed.

4.0 PREPARATION PHASE

4.1 Test Equipment

Test equipment will include a test set which will be designed to provide suitable star targets for the ST. The set will enable mounting the ST within a lightproof container to permit testing in a lighted room. The following major components are parts of the test set:

- Star field simulator
- X-Y star target translator
- Background simulator
- ST mounting
- Collimating lens
- Beamsplitters
- Theodolite mounting fixture
- Boresight calibration fixture

The unit will be portable and sufficiently rugged to preserve calibration and target orientation.

4.1.1 Test set control unit. A test console will be designed and built to provide the power and control interface to the test set, ST, and data collection system. Complete controls for test set devices and ST monitoring points will be incorporated within this unit.

4.1.2 Calculator/computer to ST interface unit. A calculator/computer to ST interface unit will be designed and

fabricated to provide the necessary interface for the test system. Physically, the unit will be housed in the control unit.

4.1.3 Data collection system. Preparation for the calculator/computer data collection system will include the complete procurement, installation, familiarization, and checkout of the calculator/computer and peripheral equipment in the laboratory.

4.2 Software

Software requirements will include the following:

4.2.1 Development model. To facilitate the testing of the development model ST, laboratory calculator/computer software will be required. This includes routines that control, calibrate, and record data.

4.2.2 Data handling programs. Calculator/computer programs will be prepared to provide for data acquisition and analysis.

5.0 SCHEDULES

The basic schedule and estimated manpower requirements of these tasks are presented in the attached diagram. The listing is preliminary because exact scheduling of ST test units is unknown. As more information becomes available, the schedule will be updated.

5.1 Documentation

In addition to this report, substantial documentation will be prepared as the program progresses. A list of proposed items to be prepared includes:

- Test plans
- Test procedures
- Test reports
- Design studies
- Design reports
- Calculator/computer programs

5.1.1 Test plans. Test plans for the evaluation will be written when ST characteristics have been finalized by the contractor and the test set design has been completed and verified. Both general and special plans will be prepared.

5.1.2 Test procedures. Test procedures can be prepared after test plan acceptance. Each procedure will contain individual characteristics which will facilitate modification during evaluation if tests indicate the need for either change or pursuance to greater depths.

5.1.3 Test reports. Test reports can be written after each phase, each test, or after the complete program as required. Test reporting will be timely and, in most cases, necessary after each test is performed.

5.1.4 Design studies. The need for design studies will vary in the program preparation and will be prepared as required.

5.1.5 Design reports. Design reporting will be done on an individual basis for selected test items and equipment as required.

5.2 Calculator/Computer Programs

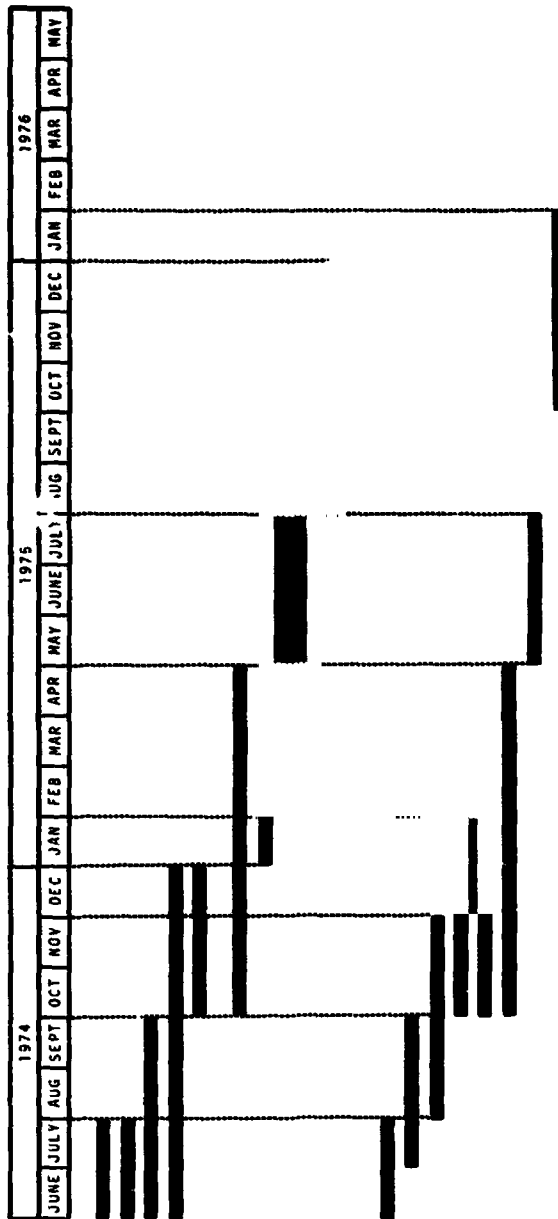
These programs will be prepared as required. Some degree of flexibility may be needed in their preparation as the test program progresses.

APPENDIX A

TEST PROGRAM SCHEDULES
AND MANPOWER REQUIREMENTS

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NASA/JSC INERTIAL/OPTICAL LABORATORY SPACE SHUTTLE ORBITER ST TEST SCHEDULE



NASA/JSC INERTIAL/OPTICAL LABORATORY SPACE SHUTTLE
ORBITER ST TEST PROGRAM MANPOWER
REQUIREMENTS

	1974						1975												1976		
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
ENGINEERS	2	2	2		3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
TECHNICIANS	1	1	1		2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1
PROGRAMMERS	0	0	0		0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0
SUPPORT SERVICES	0.5	0.5	0.5		1	1	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	3.5	3.5	3.5		6	6	6	7	7	5	6	4	4	4	3	3	3	3	3	3	3

DATE ISSUED: _____
REVISION: _____